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OCEANUS

EDITOR: JAN HAHN

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Nous verrons que nous verrons

THIS might well be the motto of oceanographers. The men on our cover leaning over the side of the R.V. 'Chain' to bring up a coring tube, are full of anxiety which may turn to joy or to disappointment. After many hours of waiting the instrument returned from a depth of 25,000 feet. "Did we get a core? Did it trip correctly? Did we hit hard bottom?" We shall see what we shall see. After another ten or fifteen minutes of struggle the 50 foot long steel barrel is laid along the deck and may lead to the excitement so well described by Dr. Nicholls in this issue.

Editorial

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FOR once we have devoted an entire issue to just one cruise of one of our research vessels. Cruise No. 17 of the R.V. 'Chain' (Captain E. H. Hiller) to the Romanche Trench on the Atlantic Equator was particularly interesting in that a large amount of diversified work was done during the 3½ months, 17,000 miles voyage. Measurements of the Atlantic Equatorial undercurrent, the finding of a passage through the Mid-Atlantic Ridge, the dredging of volcanic boulders and glass and many other interesting observations were made by a total of 29 men (and girls) in the scientific party; consisting of physicists, geologists, chemists and biologists. In addition a new method of navigation was tried out, gravity measurements were made and time exposures of the night sky were obtained possibly for the first time. All in all 'Chain' 17 was a most successful cruise.

Although the often oppressive heat did not make for the most ideal working conditions the officers and crew of the 'Chain' assisted "science" in the cheerful and co-operative manner in the tradition of the Institution's ships' personnel.

Porpoises jumping ahead of the 'Chain'.

CHAIN - 17 IN THE ROMANCHE TRENCH

By W. G. METCALF

A newly discovered passage through the Mid-Atlantic Ridge and measurements of the Atlantic Equatorial Undercurrent were some highlights of the cruise.

THE Romanche Trench Cruise was conceived in the fall of 1958 when, during the Equator Crossing of the Atlantic Ocean on the R.V. 'Crawford' as a part of our International Geophysical Year studies, our curiosity was aroused by the results of a 7,000 meter hydrographic station in the Trench. The Trench itself has been known since its discovery by the French Naval Vessel LaRomanche in the last century as a geological phenomenon of an extremely deep hole lying directly on the mid-Atlantic Ridge. The deep water of the Trench, our Crawford Station #482 showed, was of Antarctic origin with a potential temperature of 0.65°C. and an adiabatic increase in the observed temperature from a minimum of 1.10° at 5030 meters to 1.37° at 7020 meters.

The Eastern Basin of the Atlantic Ocean has considerably warmer deep water temperatures than does the Western Basin, and our IGY data suggested that the coolest Eastern Basin deep temperatures lay in the vicinity of the Romanche Trench. This led me to believe that this area might be the saddle point of the mid-Atlantic Ridge. One of the major objects of the 'Chain' cruise #17 was to check this point.

Hydrographic station on the 4-8 watch

We had hopes of an additional course of investigation in the Equatorial Region which also stemmed from our Equator cross-section in 1959. . . and that was to look for the Equatorial Undercurrent such as the one described by Knauss in the Pacific and which he has named the Cromwell Current. In the Pacific, the Cromwell Current lies on the Equator running strongly to the east only a few meters below a west flowing

surface current. A Cromwellian Current had not been described in the Atlantic, but Gordon Volkmann had suggested we look for it on the Equator crossing by means of lowering very small parachutes with the BT winch to see if an east flowing sub-surface current could be detected. Although only the crudest form of observations were made by this method, we were convinced of the existence of such a current.

Bathymetric survey

In connection with the Romanche Trench and mid-Atlantic Ridge saddle point, one of the most important things was to obtain as complete a bathymetric survey as possible of the Trench area. Therefore, the first phase of the cruise consisted almost entirely of echo-sounding work. Originally this was planned to be centered on the Trench inasmuch as I was able to convince myself from our scanty hydrographic data that this was the key to the problem of deep water communication between the Eastern and Western Basins.

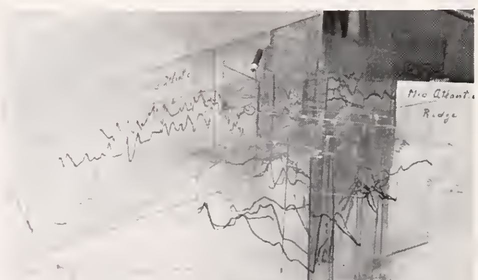
However, one weekend evening J. B. Hersey called me up and expressed considerable concern over this plan. Existing charts of the area are extremely poor in showing the contours of the Ridge, and Dr. Hersey feared that concentration on the Trench might lead us to overlook a possible saddle point he suspected might exist a few hundred miles further east along the Ridge. This sent me scurrying back to the hydrographic data files, and the information derived certainly indicated that it was a pretty risky proposition to consider the Trench as the saddle point. So it was agreed that the bathymetric survey, which was carried out by Arthur Voorhis and Elizabeth Bunce, should be expanded in scope to check the Ridge to the East. This was done, and it saved the day.

When I arrived in Freetown, Sierra Leone, to join the 'Chain' following the bathymetric survey, I

MR. METCALF is a Physical Oceanographer on our staff and joined the Institution in 1945. He was chief scientist on the second and third phases of 'Chain' Cruise #17.

was greeted by a vast array of fathograms and a wonderful three dimensional plastic model constructed by Charles Parker and Marvel Stalcup, all of which indicated that Brackett Hersey's weekend phone call had paid off. The deepest passage across the ridge apparently occurs not as a deep cut at 18° west on the Equator through the Romanche Trench but as a series of meandering canyons and mountain passes and gullies weaving their way tortuously around isolated mountain peaks and ridges in the general area of 15° west on the Equator.

Our study of the deep water communication through this region consisted of a series of hydro stations extending across the saddle region from the deep water of the Eastern Basin into the deep water of the Western Basin to determine exactly what sort of water we were dealing

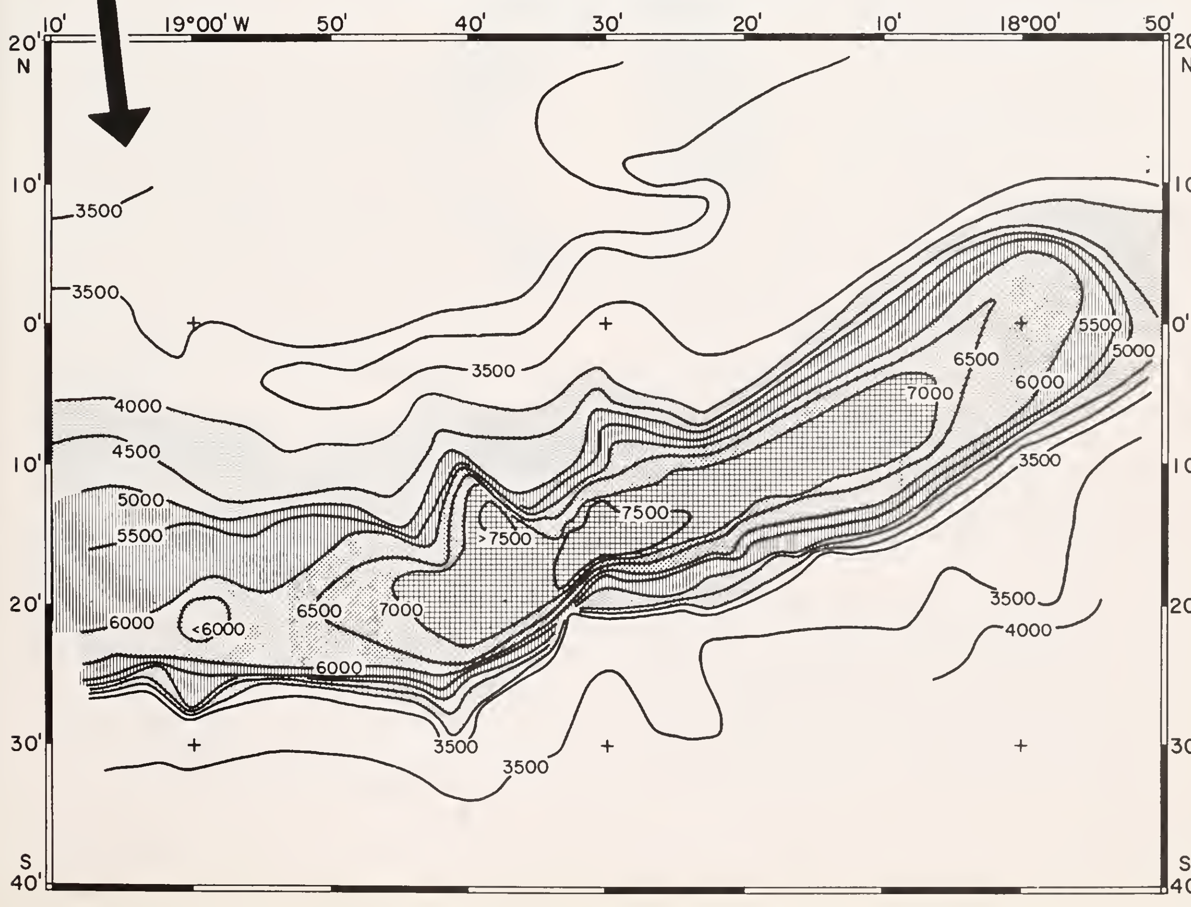


Three dimensional models made on shipboard show the Romanche Trench area in the background and the Trench details in the foreground.

▲ Bathymetric chart of the Romanche Trench area on the equator shows the newly found passage for deep water as a series of meandering canyons and mountain passes through the Mid-Atlantic Ridge at about 15° West. Contour intervals are 1000 meters. The black dots and numbers refer to hydrographic stations.

"These charts are published from preliminary data based on the Chain — 17 survey. Corrections are being applied. The final charts will be published at a later date in the scientific press."

▼ This detailed chart of the Romanche Trench was obtained while the 'Chain' steamed some 4,600 miles over an area of about 180 x 600 miles.



Lighted buoy fastened to a parachute drogue at a depth of 55 meters is towed toward the east in the Atlantic Equatorial undercurrent. The westerly surface current adds to the turbulence behind the buoy.

with. These observations were extended down to within a few meters of the bottom, scraping up mud in our Nansen bottles on many occasions. Then a series of stations parallel to the Ridge on the Eastern Basin side delineated quite closely the area where the coolest water was entering the Eastern Basin.

Tentatively, it looks as if the sill depth lies very close to 3750 meters and is in the region of about 15° West on the Equator.

At one time I had hoped to launch a Swallow-type buoy into this cool water to measure the flow, but after studying the station data, I feared it would be useless. The cool water entering the Eastern Basin appears to hug the bottom so very closely that unless one could determine the depth at which the pinger drifted within exceedingly narrow limits — say considerably less than 100 meters — one ran the risk either of having the pinger run aground while the ship "tracked" it futilely for days, or else having the pinger float a little too shallow, thus missing the cold water entirely, a fact which the observer could not readily ascertain.

Therefore, the major effort to determine the saddle of the Ridge consisted of many hundreds of miles of sounding runs and twenty or so carefully placed hydrographic stations. The analysis of the results will take considerable time before our success or lack of success is known.

A study of the Cromwellian Atlantic current next occupied our attention: First a broad survey run from north to south along 18° 30′ West was made to acquaint us with the situation, with shallow stations each degree from every 30 meters down to over 500 meters — 18 samples in all — were analyzed for temperature, salinity and dissolved oxygen content. Then a lowering to 500 meters with the Richardson current meter was made with current measurements at frequent intervals on the way down and up. This program worked out so well that a second section was made at 13° 30′ west with similar stations every thirty miles from 3° 30′ south to 3° 30′ north. In the course of this second section and on the basis of the results as they were obtained, a parachute drogue was lowered on 65 meters of polyethylene line to study the core of the east flowing sub-surface current at about 10 minutes North latitude.

The drogue and lighted buoy were launched and we watched delightedly as it started to drift rapidly to the east. Before we could get any measure of its speed, it was suddenly and inexplicably sucked down out of sight. A second effort met the same fate. For a third attempt Charles Parker improvised a more powerfully buoyant float, and a drogue launched at 2200 one evening was followed until 1730 the next evening at which time it was recovered. The only slightly disappointing feature of what was otherwise a magnificently successful experiment came from the fact that cloudy weather precluded as many celestial fixes as we could have hoped for. However, we feel that the navigational control was adequate to establish a good deal of information about the current.

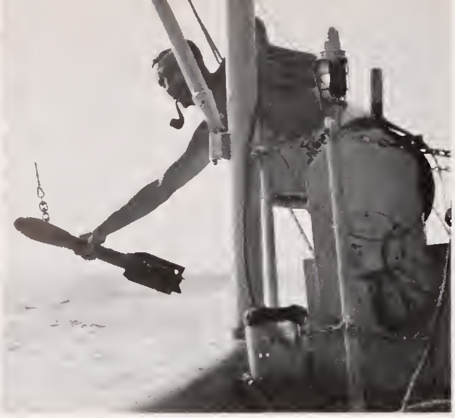
The buoy took off to the east surging through the water and leaving a wake like a moored buoy in the Woods Hole Channel with the tide running. The ship followed closely along side and repeated ship log measurement showed the surface buoy, dragged by a parachute at about 55 meters in depth, to be moving through the surface water at a speed up to 2¾ knots. Our meager celestial sights indicated that of this 2¾ knots, about ¾ of a knot was due to a westward flowing surface current and 2 knots due to the eastward flowing sub surface current.

This was written as the 'Chain' approached Sierra Leone to pick up more scientists for additional studies on the third phase of the cruise. But several of us are already laying plans for a cruise we would like to make sometime in the future when we hope to measure the subsurface current system all the way from the coast of Africa to the coast of Brazil — but in an air conditioned ship!!

New President

DURING the annual meeting on August 11, 1961, Mr. Homer H. Ewing of Wilmington, Delaware, was elected President of the Associates of the Woods Hole Oceanographic Institution. He succeeded Mr. Noel B. McLean of Stamford, Connecticut, who served as President since 1955 and was elected Chairman of the Board of Trustees of the Institution on the above date.

Mr. Ewing recently retired from the duPont Company and is widely known in industrial circles having served as President of the National Security Industrial Association and as Chairman of its Undersea Warfare Panel. He has been a member of the Board of Trustees of the Woods Hole Oceanographic Institution since 1959. We feel sure that the Associates will welcome the leadership of Mr. Ewing and congratulate Mr. McLean upon his election as Chairman of the Board of Trustees. We are most grateful for Mr. McLean's many years of service to the Associates.



Chain - 17

Some Statistics

Major purpose: To study the Romanche Trench in the Mid-Atlantic Ridge. Divided into three phases. **Ports of call:** Bermuda and Freetown, Sierra Leone. Departed Woods Hole 1 February 1961. Returned May 16, 1961.

Total miles sailed: 16,630 of which 4,601 miles were devoted to a thorough bathymetric survey of the Romanche Trench and its surroundings over an area of 180 x 600 miles.

Days at sea: 1st leg: 30 days, 12 hours, 17 minutes (more than any of our ships ever spent at sea). The longest voyage by 'Atlantis' was 28 days. **2nd leg:** 19 days, 20 hours, 11 minutes. **3rd leg:** 24 days, 15 hours, 19 minutes.

Personnel: Scientific party: 3 ladies, 26 men (not all on board on each phase). **Chief scientists: Phase 1:** Dr. A. Voorhis, **Phase 2 & 3:** Mr. Wm. G. Metcalf. **Ship's Compliment:** 29 officers and crew. **Part-time participants:** several unidentified landbirds, one of which stayed on or around the ship for five days a thousand miles from land.



18 crossings of the Equator between March 4th (day of ceremony) and April 27th. Possibly only old whaleships or lurking warships ever crossed the Equator so many times in such a short period.

Data: 1085 temperature observations and an equal number of salinity measurements, chiefly made on the second and some on the third leg of the cruise on 53 hydrographic stations. 1200 oxygen titrations, 900 total phosphate determinations, 800 insitu inorganic phosphates, and 450 samples frozen on which inorganic phosphates, silicates, nitrates and nitrites were run.

4 large volume water sample stations providing 33 water samples for fission product studies on each station. 675 bathythermograph observations. 78 plankton tows. 24 mid-water trawls. 57 parachute drogue observations. 2 big buoy drogue observations. 1 small buoy drogue observation. 20 scattering layer stations, totaling 30 hours and using some 350 lbs. of explosives. 13 lowerings of the velocimeter. 40 current shear studies. 8 piston coring tube lowerings. 17 Van Veen samples. 1 Pipe Dredge.

Routine observations: Continuous bottom recording with the Precision Graphic Recorder. Continuous observations of atmospheric and oceanic CO^2. In addition biological observations were made of visible marine life and of birds. Many surface dipnet collections were made day and night. A few hours also were spent in chasing porpoises, blackfish and sperm whales and recording their sounds.



Equatorial Undercurrents

THE recent "discoveries" of strong, shallow Equatorial undercurrents in the Pacific and in the Atlantic Ocean throw an amusing sidelight on scientific research. At first we thought: "Ah, here is a fine triumph for oceanography"! Two hitherto unknown major ocean currents comparable in volume of flow to the Gulf Stream have been found by oceanographers from the Scripps Institution of Oceanography and from the Woods Hole Oceanographic Institution. This is a triumph for our science and could be used to point out how much we still need to learn of our earth.

Now it turns out that evidence of these currents dates back some 75 years and that for some reason or other one had lost sight of the earlier works on the subject. The German oceanographer Krümmel reported in a book published in 1911 that J. Y. Buchanan on the 'Buccaneer' measured the Atlantic Equatorial Undercurrent at 55 meters moving south-east at more than one knot underneath a weak westerly-flowing surface current. Apparently the measurements were made while the ship was more or less anchored by its cable recovering line, and there was some criticism of the results because the line was dragging.

Puls (1895) observed in both oceans that when the south-east Trade Winds on the Equator died out for a period of time, an easterly-flowing current developed at the surface, and he suggested that it was constantly present as an undercurrent, coming to the surface only during extended calms.

Cromwell, Montgomery and Stroup described in 1954 the behavior of long-line fishing gear in the Equatorial Pacific leading to their positive identification of the subsurface easterly flow. Following Cromwell's death, the suggestion was made that this current be called the Cromwell Current.

On the IGY trans-Atlantic section along the Equator, made in December 1958, the behavior of the wire on the hydrographic stations convinced us of the presence of a swift shallow easterly undercurrent. Shallow casts on the stations showed a much larger easterly angle than did the deep casts where enough wire was below the current so that the current drag forces were counterbalanced.

Neumann (1960) reviewed the earlier literature on the subject and discussed the dynamic topography of the Equatorial region. He pointed to the probability of there being an Atlantic Ocean version of the Cromwell Current. Soon afterwards, Voigt (1960) reported on an anchor station occupied by the 'Mikhail Lomonosov' on the Equator at 30° West on May 1959. They found an easterly current of a knot and a half at 50 and 100 meters dropping to under a knot at 150 meters. This was during a period of calm weather, and a surface current flowing east at a knot or more was present.

On the recent cruise of the 'Chain' to the Romanche Trench, one of the major objectives of the operation was the study of this interesting feature.

We were most excited when the Atlantic Equatorial Undercurrent was indeed found to exist and were amazed by its strength. Much work needs to be done to delineate and to understand these rediscovered currents, the actual driving mechanism is unknown for either current and there are significant differences between the Pacific and the Atlantic Equatorial undercurrents which are not yet understood.

Sound Scattering

BY R. H. BACKUS

"Over the side!" goes a half pound charge of TNT.

DR. BACKUS is a marine biologist on our staff. His interests are not only in scattering layer studies but include natural studies of sharks and whales and studies of the sounds produced by marine life.

'CHAIN' Cruise 17 was especially interesting to me because it was the first of several Atlantic crossings I have made in which a wide band of latitude was covered. Most of our trans-Atlantic passages are pretty much west to east or east to west.

My principal concern on this voyage was the study of the variation in sound-scattering over the track between Africa and Woods Hole. Sound scatterers in the sea are mostly restricted to the upper few hundred meters of the water column and occur in strata (the so-called "deep scattering layers"). The most effective sound scatterers are believed to be small bathypelagic fishes with swimbladders. The gas-filled swimbladder is an effective scattering agent as its acoustic contrast is high compared with sea water and the remainder of the fish's body.

Sound-scattering may be studied in several ways. The most effective manner designed to date and the one employed on this cruise, uses the explosion of a small (one-half pound) charge of TNT as the sound source. The echoes from the scatterers are received by a hydrophone, or underwater microphone, and are stored by a magnetic tape recorder. Ashore, the tape recordings made at a number of stations along the ship's track are analyzed to show the intensity of sound-scattering as a function of depth and sound frequency.

Preliminary analyses of the data from 'Chain' 17 show that the intensity of sound-scattering is well correlated with our other observations of the relative abundance of life in the sea along the Africa to Woods Hole track. In the region from the equator north to the beginning of trade wind zone and the Sargasso Sea, sound-scattering is intense and here we saw many birds, sharks, porpoises, and whales and net hauls for deep-sea fishes were good. On entering the trade wind zone and coming into the Sargasso Sea signs of life at the sea surface became fewer, net hauls were poorer, and sound-scattering was much less intense. Such a low level of "life" was maintained until we crossed the Gulf Stream and entered the rich slope waters in the approaches to the New England coast.

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STARS and GRAVITY

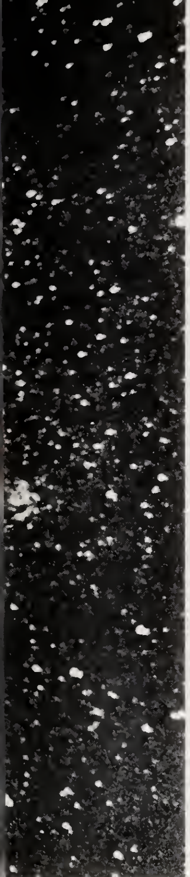
A new system of navigation, called GEON (Gyro Erected Optical Navigation System) was successfully tried out at sea during 'Chain' Cruise 17.

The system consists of a north-seeking gyrocompass rotor slaved to a second horizontal rotor oriented east-west on its spinning axis. The combination provides the gravity vertical and the geographic north point and thus, the local meridian plane. Disturbing responses to horizontal speeds and accelerations are made quite small by coupling suitable sensors to the gimbals and converting their signals into appropriate correcting torquess to precess the rotors.

Celestial navigation can be practiced at any time of the day or night when clear skies exist. Given the local vertical and north point to define the local meridian plane, Greenwich Mean Time and the celestial coordinates of a body, it is possible to fix the momentary latitude and longitude of a moving ship to one minute of arc (1 nautical mile) from a single observation, and to track its change of position with time by taking serial observations on a single celestial body.

As a by-product, the apparatus also makes it possible to take 30-minute time exposures of the sky with small cameras mounted on the gyro. The photo above shows the Milky Way in the Crux-Argo region, photographed on 19 March 1961 while the 'Chain' was underway at 13 knots in lat. 00-10 South and long. 18-44 West. Compensations for roll, pitch and yaw were provided by the Sperry Mark 19 Meridian gyrocompass. Corrections for the ship's motion in latitude and longitude as well as for the earth's rotation were provided by hand guiding on Spica.

See: "Applications of the Gyropendulum", by W. S. von Arx, The Seas, Ideas and Observations; Interscience Press, N.Y. (in press).



VON ARX

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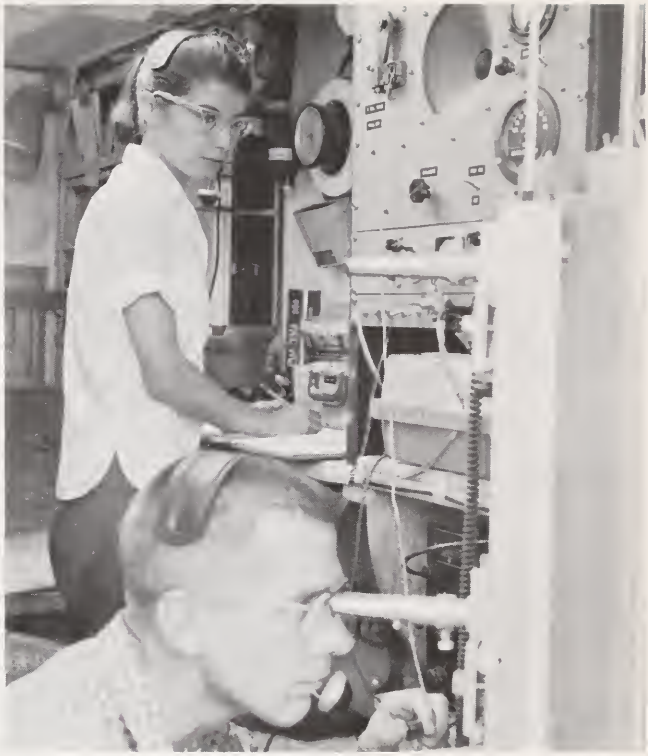
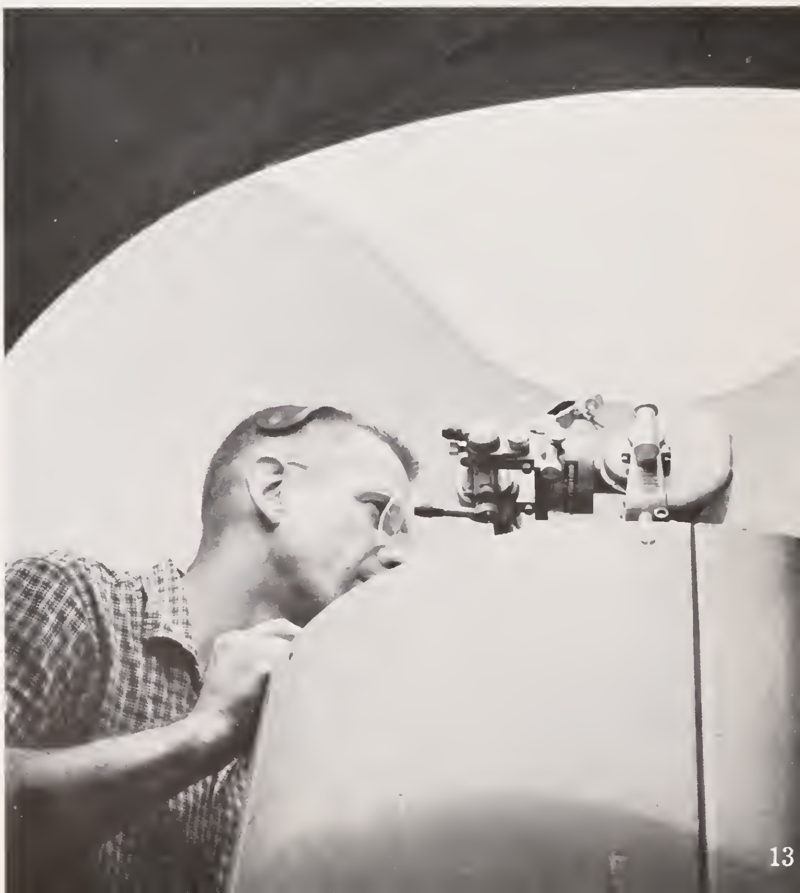


D. W. S. von Arx, assisted by Lorraine Barbour, making a gravity observation in the box-sized laboratory observatory mounted on the boat deck of the 'Chain'. The gravimeter employs a non-magnetic steel ball falling slowly through silicone oil of very high viscosity.

jL

Star observations for navigation could be made by day or night with the aid of a small equatorially mounted theodolite, fixed to the head of a meridian gyrocompass.



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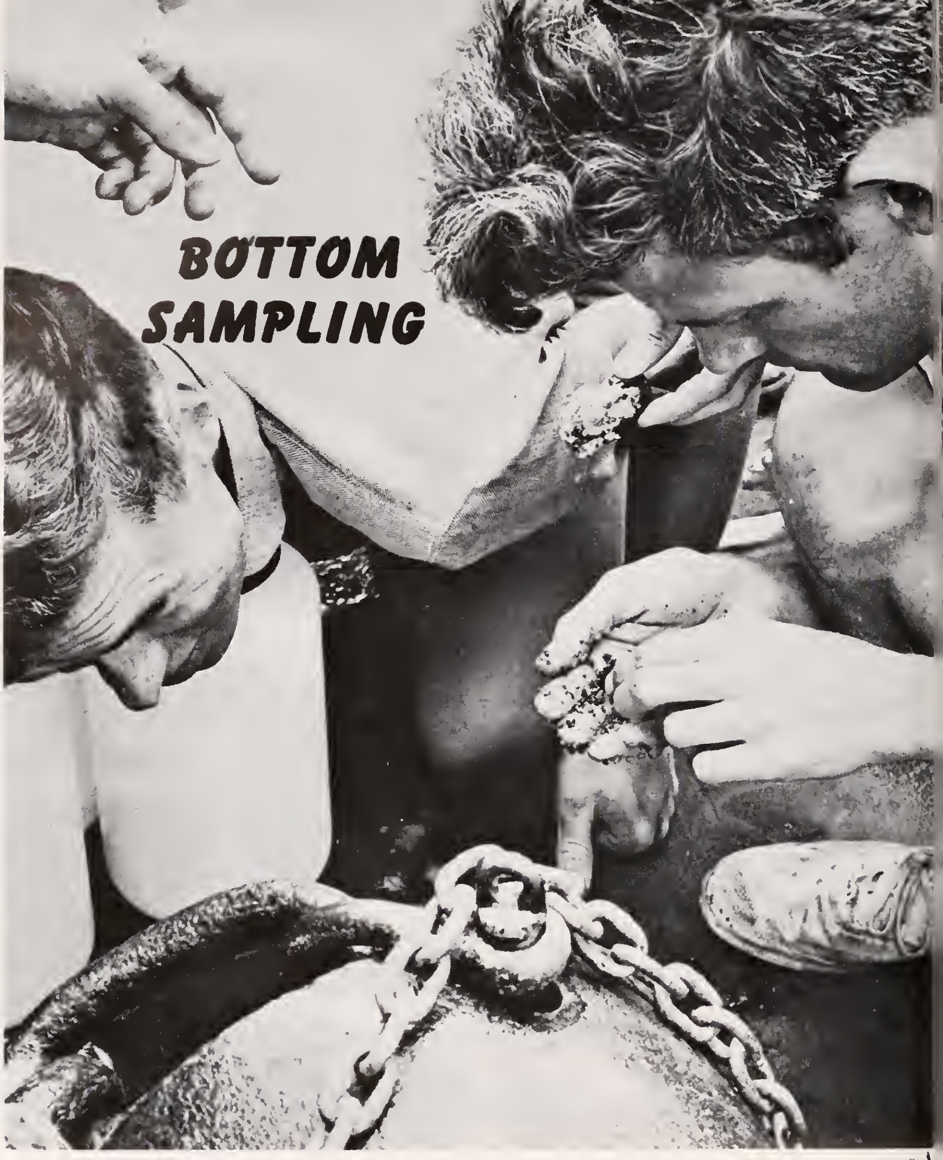


BOTTOM SAMPLING

BY G. D. NICHOLLS

MUCH effort has been, and is being, expended in studies of the seas and oceans as they now exist. Much more still remains to be done. Yet it is not too early for speculation on the development of the oceans, how the waters came to acquire their present complexities, how the basins evolved. Speculation has its place in science but it can never substitute for investigation. The need for such investigation is obvious. The oceans as we know them are but a stage in a continually changing sequence. To understand them fully, even in their present form, we must know something of the earlier pictures in this kaleidoscope of time. History leaves its imprint on the material world no less than on the mental processes of man; no scientist studying any part of the planet Earth can neglect the time factor.

Though the need is obvious the methods to be used are less so. Geologists, in their studies of Earth's development have long believed that "the record of the past is written in the rocks." For the oceanographer the record of the past is written in the sediments of the ocean floor. We must learn to read that writing, to interpret the meaning of what we see and find in these sediments so that, one day, we may understand something of the nature and form of the oceans in the long stretches of time before man arrived to study them.

Traditionally, geologists have attempted deductions about earlier conditions from the nature of fossils found in deposits formed in those remote times, or, more precisely, from the character of fossil assemblages. Investigations of sub-surface geology by means of boreholes, with its restriction of the amount of material available for study, stimulated interest in micropalaeontology — the study of micro-fossils. Over the last decade or so the possibility of pushing this line of approach to its logical conclusion has been explored, viz, — using the atoms themselves, of which the rocks and sediments are composed, as "fossils". The relative proportions of the chemical elements and their location in different components of the sediment are influenced by the conditions of sedimentation and the character of the water in which the sediments accumulate. Sufficient work has already been completed to indicate that this approach holds considerable promise as a means of deducing conditions in bodies of water on the surface of the planet in remote times. Some of the critical chemical elements in such studies are present in sediments in only trace amount, calling, for very careful analytical techniques for their determination, but the science of sedimentary geochemistry is developing fast as more and more of the analytical problems are solved. To a considerable degree micropalaeontology and sedimentary geochemistry complement each other and we may hope that the use of both approaches in the study of deep sea sediments will produce much information relative to the development of the oceans. These, then, are our methods.

Dr. Vaughan T. Bowen early recognized the significance of the new geochemical approach to sedimentation in oceanographic studies and contacted the author of this article during a visit of the latter to various geological institutions in U.S.A. in 1956-57. One outcome of our discussions was the bottom sampling program undertaken by R.V. 'Chain' on the third leg of cruise #17 from Freetown, Sierra Leone, to Bermuda. Five sediment cores ranging in length from 24 feet to 37.5 feet were taken at pre-determined stations meeting the requirements of a sedimentary geochemical investigation of the ocean floor. One of these cores was raised from a depth of 7,610 metres in the Romanche Trench and study of it should throw interesting light on the origin of that remarkable topographic feature.

Long hours

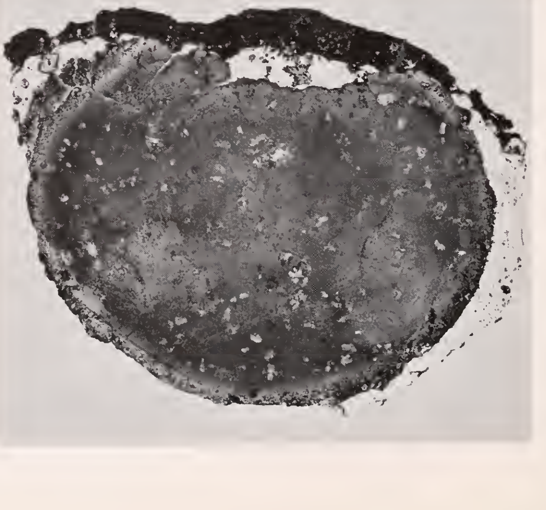
The requirements of a geochemical investigation impose quite stringent controls on the sampling of cores of deep sea sediments. Great caution must be exercised to avoid contamination from any source. Furthermore, until we are more fully aware of the possible extent of diffusion of chemical elements, especially those in trace amount, in the interstitial waters of the sediments, the only wise course is to extrude and sample the cores as soon as possible after collection. Aboard the 'Chain' extrusion from the core barrels and sampling was initiated immediately the cores came over the side. While the sympathetic concern of the 'Chain's' company over long hours spent at the extrusion table is appreciated, it may be pointed out here that no scientist, having at last got the cores he wants on the extrusion table, would willingly yield the sampling knife to any other. Thousands of miles and months of waiting precede those exciting moments when the sediment cores begin to slide from their enclosing barrels. The need for sleep is a most exasperating natural weakness of the human frame at such times. Fortunately, on each occasion the core was 'cleared' before 'Chain' reached the next station and progress was never held up by the sampling stipulations of our geochemical program.

Exciting discovery

Successful and satisfactory as our coring program was, the most exciting part of the bottom sampling work was not part of the planned program at all. On May 6th an attempt was made to obtain a sediment core from the eastern flank of the Mid-Atlantic Ridge at latitude 19°23′ N. As is well known, the bottom topography on the flank of the ridge is highly irregular with many topographic high (hills) separated by lows (depressions). The corer was lowered over a depression where the water depth was approximately 2,650 fathoms but even as the corer went down 'Chain' drifted over a hill and by the time the corer was nearing the sea floor the depth was only 2,420 fathoms. The danger of the corer being buckled by contact with a solid floor was considered but, after some deliberation, it was decided to continue with the operation. Let it be admitted now that secret daydreams were being entertained that we might, we just might, get a sample of the solid rock from beneath the sediments in such a location. Dame Fortune had smiled so sweetly hitherto that she might even go that far. The time required for raising the corer to the surface seemed interminable. Only those who endured that waiting can fully appreciate the excitement as the main corer was examined — or the acute and stabbing disappointment at finding it empty. Some minutes of disconsolation passed before the pilot corer was checked. As the liner slid out of the pilot tube all disappointment evaporated in a burst of elation for the liner held red clay and in addition a fragment of the solid rock from beneath the sediment of the ocean floor — a freshly broken fragment of a dark natural glass. Subseqent examination of the piston of the main corer showed red clay stuck on its end and, embedded in the clay, shards of the same glass. Many boulders have been dredged from the floor of the Atlantic over the

A volcanic boulder, about one foot long, was brought up by hauling a pipe dredge up the western slope of the central valley on the Mid-Atlantic Ridge. The haul was made between depths of 1910 fathoms to 1542 fathoms.

A section of the boulder shows a white rim consisting of loosely aggregated modern foraminifera coated by manganese where the boulder was exposed.



years which are almost certainly locally derived. But they cannot be proved to be representative of the sub-sediment surface in the same way as can the fragment broken and recovered from that surface on the afternoon of May 6th. At last speculation can give place to investigation — at last we have a sample indisputably from the sub-sediment surface. I do not consider it too extravagant a claim that this cruise would have been justified if this specimen alone had been won from the waters of the Atlantic. Yet to fill our cup of success to the brim an hour or so later we raised a 30 foot core of sediment from an adjoining area.

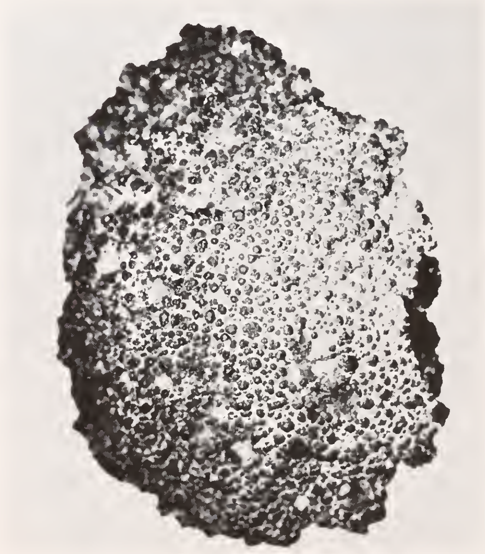
So it is that we look back on a bottom sampling program successful beyond all our hopes. Though much work has to be done before our samples yield their secrets to us, the program for geochemical investigation of deep sea sediments of the equatorial Atlantic has got off to a most auspicious start.

Ending on a personal note I wish to thank all those who helped to make this cruise so successful. Richard C. Leahy, Peter L. Sachs and George L. Erlanger laboured long and willingly. Dr. Bowen's never-flagging faith and encouragement were a constant source of inspiration. To these and many others I tender my sincere thanks.

DR. NICHOLLS, is Associate in Geochemistry on our staff and lecturer at the Department of Geology of the University of Manchester, England.

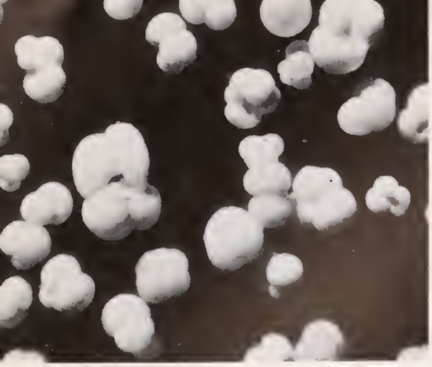
ARENDS

At a depth of about 25,000 feet a deepsea holothurian was photographed by an Edgerton camera in the Romanche Trench. Recently our colleagues at the Lamont Geological Observatory took a photo of a whole group of Holothurians in the Chilean Trench. Both photos are the deepest known views of these bottom dwellers. The animal shown is about 6 inches long and is closest to Penagione incerta Theel, known to grow to about three inches.



BRAY

A manganese covered piece of ancient Foraminifera cemented together by opaline cilica.



Foraminifera

By R. Cifelli

The most common sea shells are but little known to most people, yet provide a history of the earth.

THE Foraminifera are inconspicuous because of their small size — mostly about the size of a sand grain, though some fossil giants were several inches long — and are little known to most people. Yet these unicellular shelled animals are found almost everywhere in our Recent seas and are of great geologic importance. Foraminifera are, in fact, among the most common of shelled animals. They are widely distributed in marine rocks throughout the geologic column from the Lower Paleozoic to the Recent and probably no other group of organisms has had such a long, continuous history preserved. The Foraminifera are widely used by geologists for the correlation of rock strata and for the interpretation of ancient environments.

Foraminifera are found in all marine environments from brackish marshes to abyssal depths. Most species are benthonic and crawl on the sediments of the sea bottom or are attached to sea weed and other objects. A few species are pelagic and live floating in the water above the bottom as part of the planktonic fauna. The remains of the animals, after death, sink to the sea bottom where they accumulate in enormous numbers. In the shoaler parts of the deep sea, where little sediment is received from land, the shells of pelagic Foraminifera form sticky, shelly deposits called Globigerina oozes, because of the predominant occurrence of Globigerina and other pelagic species. At great depths, below about 15,000 feet, Foraminifera do not accumulate because the shells are dissolved in the cold, calcium poor waters.

The Foraminifera are valuable in the study of deep sea sediments, and are used as indicators of geologic ages and past marine environments. Sediments as old as Cretaceous have been penetrated by cores and recognized by the occurrences of extinct species of pelagic Foraminifera. Most cores, however, do not penetrate below the Pleistocene, because of the short length of the coring devices.

The Foraminiferal material collected from the Romanche Trench cruise is extremely valuable because it comes from a remote, not easily accessable part of the world. Plankton samples were collected along the entire traverse from Bermuda to the equator, thus covering an unusually large range of latitude and representing a unique opportunity to study the distribution of living forams during one cruise.

The five cores collected in the Equatorial Atlantic and southern part of the North Atlantic contained layers rich in Foraminifera. One of the cores came from the bottom of the Romanche Trench, at a depth of over 24,000 feet. There are no Foraminifera at the top of the core, as would be expected, since at that great depth the shells are dissolved before they reach the bottom. However, at some depth below the top of the core there is a thick layer of almost pure Globigerina ooze. A similar appearing ooze occurs on the surface of the bottom on the slope of the trench at a much shallower depth. It is too soon to speculate on the origin of the ooze in the core, but its presence there has an important bearing on the history and past conditions of the trench.

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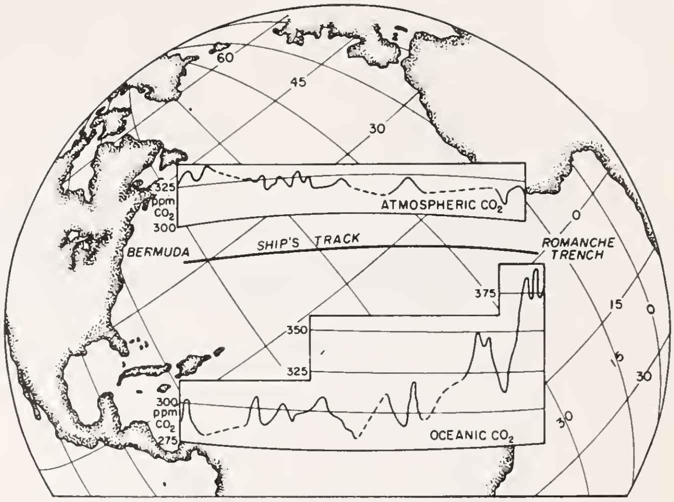
Carbon Dioxide



BY R. G. LEAHY

SINCE the middle of the 19th century the normal cycle of carbon dioxide in the ocean and the atmosphere has been affected by the increased burning of fossil fuels.* It has long been realized that this action could result in an increase in the amount of CO^2 in the atmosphere and the oceans; and since such an increase would markedly affect the earth's weather, this process has been the subject of considerable research and speculation.

The cruise of the 'Chain' to the Romanche Trench offered a valuable opportunity to study the exchange of carbon dioxide across the sea surface, as the ship's track covered a wide range of latitude and hence encountered a great diversity of oceanographic conditions. Since the level of carbon dioxide is dependent, among other things, upon temperature, pressure and biological activity it had been predicted that there should be areas in the ocean where carbon dioxide is taken up by the sea and other areas where the sea is releasing carbon dioxide to the atmosphere.

To study this problem an infrared analyzer was set up on board the ship and arranged to monitor the atmospheric and surface sea water CO^2 levels. In addition, measurements were made of the acidity of surface sea water and of various meteorological parameters. In general it was found that the carbon dioxide levels in the ocean increased with increasing surface water temperature, a result that would be expected on the basis of the solubility of CO^2 in sea water. Commonly, the levels recorded at higher latitudes indicated that the water was undersaturated with respect to the atmosphere while in the tropics the reverse was the case. This tendency can be seen on the diagram which illustrates the values recorded along the ship's track between Bermuda and the Romanche trench. One particularly interesting aspect of this section was the indication of supersaturated water in an area that correlates with the position of the Atlantic Equatorial undercurrent. Although not presently understood, these CO^2 levels are undoubtedly related to the mechanism of the formation and maintenance of the undercurrent.

The values recorded for trade wind air are similar to those recorded during previous studies in the western Equatorial Atlantic. The relative constancy of values measured under similar meteorological conditions was also in agreement with earlier studies, but under certain circumstances parallel daily variations of the surface sea water and atmospheric values were noted but have not yet been satisfactorily explained. These diurnal variations suggest that the transfer of CO^2 across the sea surface can take place quite rapidly.

On the other hand, an analysis of the records showed evident differences in the atmospheric and surface sea water CO^2 levels which is indicative of a rather slow exchange rate. This slow rate is in accordance with previous investigations carried out at the Institution and precludes the possibility of the tropical ocean being a sink and an effective reservoir for atmospheric carbon dioxide.

*See: "Sun, Sea and Air", Oceanus, Vol. V, nos. 3 & 4.

Radioactive Isotope Studies

BY V. T. BOWEN

Studies of radioactive elements in the sea indicate that bomb test debris returns at a much higher rate on the ocean than on land.

A major activity within the Institution's geochemistry program for some years now, has been the analysis of the changing distribution of long-lived radioisotopes from fallout in the Atlantic Ocean. These isotopes in general were not measurably present in sea water before mid-1954, and measurable amounts have been delivered to the Atlantic Ocean only by bomb-test fallout precipitation onto the sea surface, hence study of their distributions in sea water, both horizontally and vertically, permits us to see how rapidly various chemical elements move from the upper layers toward their final end in the bottom sediments. By relating this information to other factors, we can also tell something about the mechanisms responsible for these movements. And in cases of particular elements which can be shown to move only as the water itself moves, we can see how rapidly water masses interchange across their boundaries, and how rapidly they homogenize within these boundaries. In addition, once we have a clear picture of the distribution, both horizontal and vertical, in an ocean area, this can be used, by comparison with data from land and island stations, to study the total fallout delivery in various periods of time. From this we can compare either the rates of precipitation in the meteorological sense, or the mechanics of precipitation; unfortunately this data does not allow us to argue simultaneously both of these meteorological questions.

It is one of the exciting things about oceanography that so often this experience arises: a series of measurements undertaken for a specific and relatively narrow purpose proves to be giving information of very broad interest in several related areas of study. The spreading impact of these fallout studies has been a satisfactory example.

Sampling Problems

Before going into a discussion of results or of cruise planning, we should point out that although the amounts of radioactivity involved in these studies are measurable, they are only barely so. Even though we use highly refined counting procedures, modeled to a great extent on those used for carbon-14 dating, we still require 15-gallon samples of sea water, and would use larger samples if not limited by the cargo capacity of our research vessels. Because the certainty of accuracy provided by analyses of duplicate samples is more important than the improvement in precision produced by a two-fold increase in counting rate, we collect 36.5 gallon samples from which we bring back two 15 gallon duplicates.

Catching such samples of sea water from all depths is a time consuming and laborious task at best, and it has taken some years and a lot of ingenuity both from the Institution's instrument shop, and from the expert gear handlers at sea, to achieve our best. The gadget used was a product

of the ideas and experience of R. H. Bodman and L. V. Slabaugh of the Shop, reacting with the plaintive expressions and mechanical non-dexterity of the man with the problem. It has recently been described for journal publication. These samplers first were used in 1958 on 'Crawford' 22, the equatorial crossings during the International Geophysical Year from which the present Romanche cruise developed. Enough sample is brought in for a variety of other analyses as well as for the fission product studies. And since the samplers are lined throughout with a plastic like Teflon (Kel-F), and use polyethylene valves, the water caught in them is useful for most biological, physical and chemical purposes.

Our idea in planning on large volume sampling has always been that we should concentrate on a device suitable for use on the usual hydrographic wire (3/16 or 5/32 inch diameter). This has implied restriction to devices such as the present one, which provide only one sample per lowering. Furthermore, the effort to make a device which can be handled on a rolling deck with greatest ease and least hazard, led to the samplers being light in relation to their size. This in turn means that if they are lowered beyond a definite maximum speed, the wire sinks faster than the sampler and a tangle results. This speed for 3/16 wire is about 2700 meters an hour, and defines the limit of the rate at which samplers can be completed. A whole station of nine samples from surface to 4000 meters, for instance, requires close to ten hours hove to. In addition, a complete hydro station is needed, taken when possible just before the large sample station.

Previous Cruises

Our fallout analyses have so far dealt largely with strontium-90, cerium-144 and promethium-147; we have also made a small number of analyses of cesium-137. Of these isotopes, we are inclined to believe that strontium and cesium move in the ocean only as solutes; that is, the overwhelmingly major amount of each of these exists dissolved in the water, and significant movement either horizontally or vertically requires comparable movement of the mass of water. On the other hand, cerium and promethium seem to be largely associated with the small particles of solid matter in ocean water; these have rates of vertical movement different from those of the water masses in which they are suspended.

In the cases of strontium and cesium, our view, summarized above, is not unanimously held. Under special circumstances both of these elements are strongly concentrated by living things, and consequently the possibility exists that the elements, and necessarily the isotopes of concern to us, are moved vertically in the water column in the bodies of organisms. We think that in the open ocean this is not occurring for these two isotopes to a significant extent. Our arguments are complicated, but may be summarized as follows: Both isotopes are present in fallout, whether dry or rain, in wholly soluble form. The strontium-90 must then be assumed, on hitting the sea surface to mix isotopically with the rather large amount of stable (naturally occurring) strontium in surface sea water, and chemically with the much larger amount of stable calcium. Once this mixing has taken place no organism can remove strontium-90 from the water without simultaneously removing stable strontium in proportion, and most organisms must also remove stable calcium in the same or even higher proportion. In the case of strontium-90 we are talking about vertical transfer across the 100 meter level of 20 to 50 per cent per year, a removal of the stable strontium or calcium which would be readily seen in chemical analyses as a depletion in surface waters and an enrichment at deeper levels. In fact, however, no such effects are

seen in the observed value of calcium or strontium. This would appear in case of isotope removal by transfer downward of an amount of "labeled" water, which is replaced by water of closely similar chemical but different isotopic composition.

Although the stable cesium concentration in sea water is much less than the strontium concentration, there is enough combined with the large amount of potassium (which organisms generally cannot distinguish from cesium), so that marine creatures do not often take up the cesium from as much water as ten times their own volume. Such low concentration factors are not effective in moving significant amounts of either radioisotope or element. Another line of argument stems from the fact that the ratio of strontium-90 to cesium-137 in surface water does not vary widely, and is close to the ratios both in rain and in fission production. Since organisms do not take up these two radioisotopes, or their elements, in one to one ratio, it is most unlikely that mass transport by living things could result in an unchanged ratio in the water, or in a uniform ratio at all.

Strontium-90

Measurable amounts of strontium-90 were not added to the Atlantic Ocean until the bomb tests of spring, 1954; we may take July 1, 1954 as our starting date. By spring and summer of 1957, however, samples from 300 to 500 meters deep showed strontium-90 with 30 to 50% of the surface concentration; smaller but measurable amounts were seen in some samples from 1000 to 1200 meters. In July of 1958, stations taken in the Sargasso Sea again showed this pattern; from 300 almost to 700 meters about half the concentration found in the upper 100 meters, and at 1000 meters almost half the 700 meter concentration. If we assume that no significant strontium-90 was yet to be found below 1000 meters — an assumption almost certainly unwarranted — integration of these figures still shows more than four times as much strontium-90 in the water column below 100 meters as above that level. This generally distributed downward motion has taken place at a higher rate and to a greater depth than had been thought likely either from conventional hydrographic studies, or from other estimations of naturally occurring radioisotopes like carbon-14 or radium. The repeated demonstration that these movements do take place has already convinced some carbon-14 students, and wider acceptance is being steadily achieved, indicated among other things by interest from other laboratories in making measurements of strontium-90.

Another, and more puzzling fact came from these stations: that the ocean water column contains more strontium-90 per unit area, than does the land surface at comparable latitudes; about three times as much in fact. After a very careful reexamination of our now more extensive data, we have concluded this is real: that bomb test debris returns to earth's surface at a much higher rate on the ocean than on land. This has been partly confirmed by Weather Bureau studies showing higher fallout per unit area at coastal than at inland stations, and still higher values for islands, though in each case well below our estimates for the surface of the open ocean. No idea yet exists for the mechanism producing this high sea surface fallout; it does fit recent ideas that fallout remains in the stratosphere for much shorter times than was previously estimated.

Cerium-144 and Promethium-147

When we began this study, these isotopes were expected to be treated in the oceans exactly alike, each associating with the surfaces of particles and sinking through the water column at the velocity of these sinking particles. This has not proved quite so simple: although both cerium and promethium separate from strontium under conditions

which convince us they do sink in association with particles, they also separate from each other, cerium tending to stay longer in the upper layers. Somewhat involved arguments from the chemistry of cerium at very high dilutions under conditions found in sea-water, lead us to conclude that promethium associates largely with inorganic particles sinking at rates much faster than 100 meters a month; cerium, we think, associates with particles of high organic content; two populations of cerium labelled particles are in evidence in our stations, one sinking at about 100 meters a month, the other at no more than half that rate.

It seems thus that from changes in the ratio of promethium to strontium radioactivity we may draw conclusions about the total surface area of particles sinking through a water mass in a given time, and from changes in the ratios of cerium to strontium and to promethium radioactivities, conclusions about the organic vs. inorganic nature of these particles. Unfortunately, little parallel data exists to be used in testing the conclusions resulting from this hypothesis.

The Romanche Trench

As mentioned above, 'Chain' 17 was really conceived during the International Geophysical Year cruise of R.V. 'Crawford' across the equator from east to west. On this cruise several of us first saw the depth profile of the Romanche Trench, first saw the current system along the equator, flowing at surface from east to west, and at only about 75 meters down much more strongly from west to east, and left with many more questions than, it has proved, could be answered even by one more cruise to the same area. Two large volume stations were made on the equator, one a 9° 41′ West and one at 33° 40′ west. Thus, this first time we neatly missed the Trench. The fission product distribution in the two stations is complicated, and not yet fully analyzed. One interesting and

DR. BOWEN is a Geochemist on our staff. He also is a lecturer in Zoology at Yale University.

wholly unexpected point did, however, appear: rather than the expected strong horizontal homogeneity induced by the current systems, we found vertical homogeneity; at both stations down to below 300 meters the surface value for strontium-90 was found, but this value at 9° 41′ west was just half that found at 33° 40′ west. This seems impossible to reconcile with the picture which one ordinarily draws of the effect of two rapid currents flowing in opposite directions. It is further complicated by the finding that surface values about 40° west are the same at 24° south, at the equator and at 4° and 8° north, whereas that at 9° 41′ west on the equator is very close to, though slightly lower than that at 24° south, 7° east.

It was primarily to elucidate this set of observations that the large-volume sampling of 'Chain' 17 was originally planned. Unfortunately, problems of ship scheduling while on the equator forced us to reduce the number of stations made there to just one, in the Romanche Trench. Analyses of these samples will substantially confirm or question the results of 'Crawford' 22, but will not give enough information to improve our picture of what mechanisms may be producing the observed patterns. In addition to the samples taken at depths down to about 2500 meters, from which we expect to see fission product distribution, samples were taken at 5000 and at 7100 meters, in the cold water mass below the Trench's sill, to be analyzed for carbon-14. It is hoped that these may yield data which can help tell the time of the last intrusion into the Trench of Antarctic Bottom Water from the western basin, as well as telling something about rates of vertical movement in the Trench's isolated, very homogeneous mass of deep water.

The curtailment of our work on the equator had been decided on the basis of misinformation. This permitted us to add some stations on the run returning to Woods Hole. Of these, two were in the eastern Atlantic basin, one at 5° 15′ north, 23° 30′ west was planned to coincide with a region of divergence, or upwelling, inferred by Defant, and indicated by our profile of CO^2 concentrations made on the run out. The second, at 11° 2′ north, 29° 38′ west, was planned to give an uncomplicated — if such is possible — view of conditions in the Cape Verde Basin, to compare with our stations at various points in the western basin. Here also deep samples, at 4000 and 5400 meters, were taken for carbon-14 measurements. In addition to these, several surface samples taken for fission products and carbon-14, will indicate the agreement in respect to north-south uniformity between east and western basins. Finally a station from surface to 1500 meters was made in the southeast quadrant of the Sargasso Sea, at 29° 15′ north, 57° 31′ west, chiefly for comparison with our other stations from near Bermuda, and from the northwest quadrant.

All of the stations were exceptionally successful. This was due partly to the fine weather, extreme steadiness of 'Chain' and the high efficiency of our gear and its handling aboard. In addition, the availability of the salinometer, now able to return measurements within 15 to 20 minutes of obtaining the samples, enabled us to identify immediately the small number of malfunctions (three in all) and repeat these lowerings until good samples were obtained.

Now we face a tantalizing wait: from the start of sample processing, begun for these 'Chain' 17 samples in mid-August, about three months is required before the strontium-90 analyses for the first samples are complete. From then on data rolls in at the rate of about six samples each two weeks, if nothing goes wrong. So we may well know the results of the first station, in the Trench, by early January, 1962.

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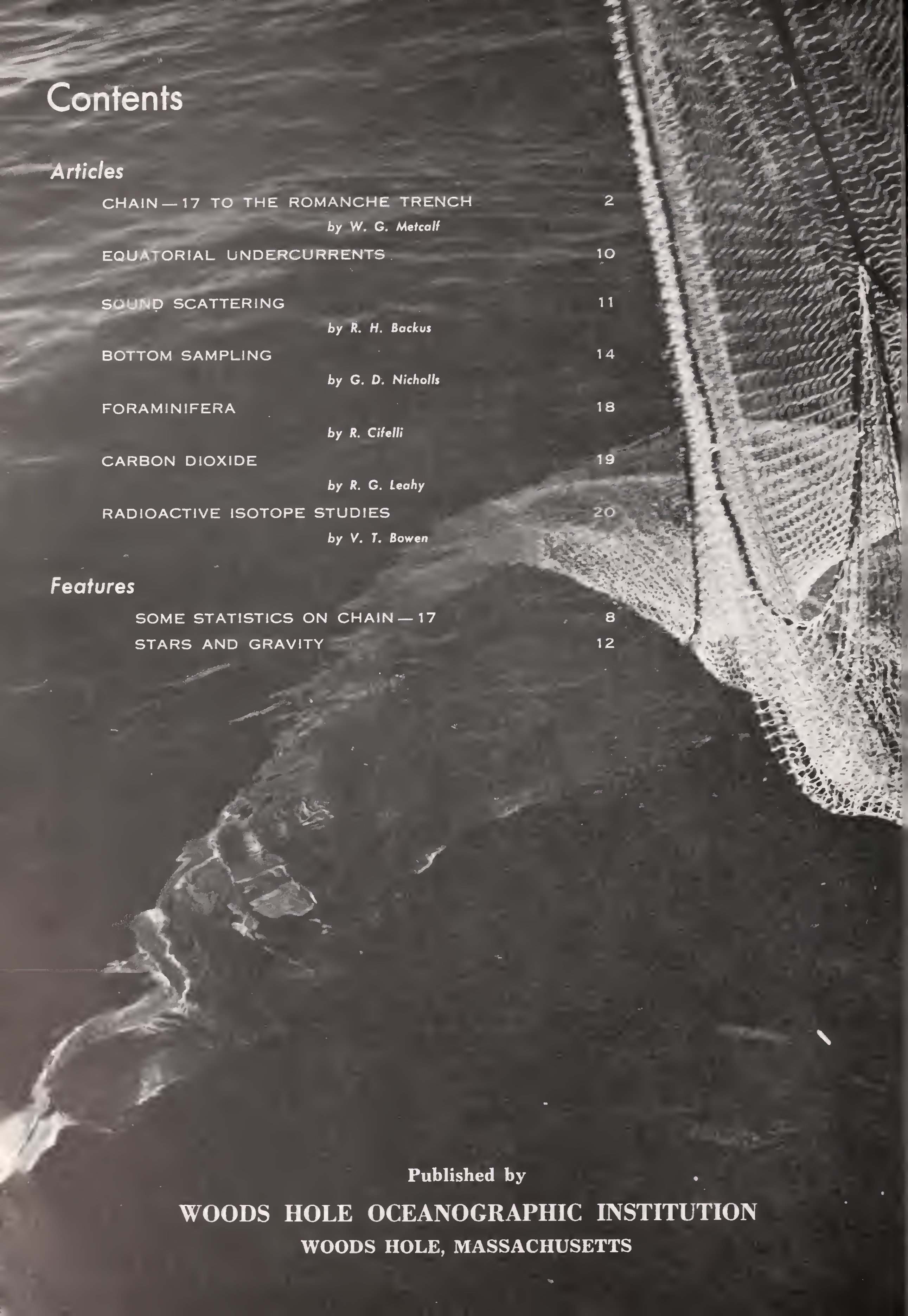

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